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the effect that it might be advantageous for colleges and universities to demand that a certain number of admission units, say ten or twelve, be confined to a small number of subjects, say three or four, and that only a definite minimum be made up of isolated subjects. After much discussion, it was voted without dissent that these questions be referred to the constituent bodies for consideration and advice; and for that purpose the following circular letter was later prepared by Dean Keppel and Secretary Furst for submission to the members of the organizations whose delegates constitute the National Conference Committee on Standards of Colleges and Secondary Schools:

In spite of the marked progress toward uniformity in college entrance credits, this committee is informed of certain recurring difficulties in administration. It appears, for example, from our general inquiry concerning the subject, that elementary algebra is usually given more time than is represented by the unit and a half of credit given to this subject, and that certain branches of history are usually given less time than is represented by the unit of credit that they receive. There is, on the other hand, a tendency toward a strictly mechanical interpretation of the unit, even to the point of counting minutes, which emphasizes the letter rather than the spirit of a system of merely approximate measures.

The committee realizes the importance of recommending as few changes in the regulations as possible, but it believes that it will be of service if the organizations that it represents will consider and report to the committee their official judgment or the attitude of their members toward the following suggestions:

A. That the unit credits assigned to the subjects of elementary algebra and history be modified so as to represent more nearly the amount of time given to these subjects.

B. That in certain subjects—as for example, history—the amount of credit to be assigned should not be uniform in all cases but should vary with the time and attention given.

C. That some distinction be made between the amount of credit that is given to subjects taken in the early years of the high school and those taken in the later years.

D. That there be adopted some uniform plan of limiting the number of subjects in which credit may be gained in order that continuity of work may be secured in at least two subjects.

The committee having received many requests for a uniform blank for the submission to the college of a statement of the school record, and it being understood that committees of the Association of Colleges and Preparatory Schools and of the College and University Presidents Association of Pennsylvania are already engaged in the preparation of such a paper, it was voted that the subcommittee seek information on this subject, consult with other committees, and report to the committee at its next meeting.

Commissioner Claxton asked that the National Conference Committee undertake the task of defining many terms which have come into use in modern education, school administration, etc., and have not had certain and clear meanings assigned to them. It was agreed that the committee should undertake this work with the expectation that some part of it, at least, could be successfully accomplished. It was accordingly voted that the subcommittee be instructed to take this subject under consideration with a view to the extension of the field of the committee to the desired determination of definitions and that a report be made at the next meeting.

Officers for the ensuing year were elected as follows:

President, Headmaster Wilson Farrand.
Vice-president, Chancellor James H. Kirkland.
Secretary-treasurer, Dean Frederick C. Ferry.

The choice of the subcommittee was left to the president with the provision that he serve as its chairman. The other members, as appointed by him, are Chancellor Kirkland, Dean Ferry and Dean Keppel.

Frederick C. Ferry,
Secretary

SPECIAL ARTICLES

THE "MULTIPLE UNIT" SYSTEM AS A SOURCE OF ELECTRICITY FOR LABORATORIES [1]

The problem of furnishing electricity, adapted to physiologic and pharmacologic ex-

[1] From the pharmacology laboratory of the Northwestern University Medical School.

perimental work, has been satisfactorily solved in but few laboratories. Very little on the subject is found in the literature and the need of a practical method which is comprehensive and can be intelligently adopted, is becoming apparent. With this in mind the writer presents a brief discussion of the sources of electricity suitable to laboratory use, with special reference to what he terms the "multiple unit" system.

Dry batteries are extensively used chiefly because of their compactness, ease in handling and apparent cheapness. But they are not dependable, since they polarize easily, the current is not constant and the supply is limited. Because of this much time is often lost in getting apparatus to work properly. In addition the cost per year is usually a considerable item. Yet in spite of these inconveniences they still remain the common source of electrical supply. Wet batteries have the same disadvantages as dry cells. They are also clumsy and hence little used. Storage cells are fairly reliable but their bulkiness and expense make them undesirable for student work.

The direct electric lighting current is an excellent source. A suitable resistance wire is attached in series to this as a rheocord from which sufficient current may be tapped off at various points and led to different instruments. The principle involved is well known, although it appears that but few physiologic or pharmacologic laboratories are utilizing it. This shunt rheocord system has the advantage of being absolutely reliable. The current is of unlimited supply and the voltage or amperage can be either made constant or varied at will. This is important in the stimulation of tissues with the direct current, where graded amounts are desired. Such an outfit may be made compact, accessible and inexpensive; it requires little care and will last indefinitely.

The installation of such a system involves several important considerations.

First, Source.—Preferably, a direct 110-volt current should be used.

Second, Amperage Carried.—This is determined largely by (*a*) the amount of current necessary to make any instrument work properly, (*b*) the internal resistance of each, and (*c*) the number of instruments to be used and their effect upon the line amperage when shunted into the line resistance. Most inductoria of American make operate best with a current of .5 to 1 ampere and 1.5 to 2 volts. The Harvard coil has an internal resistance of about .5 ohm, but this may rise as high as 1 ohm with the interrupter in series if the contact points of the latter are poor. The Stoelting make No. 7090 has 1.5 ohms, and 2 ohms or more with the interrupter. Signal magnets all work well with 1.5 to 2 volts and .5 to 1.5 amperes. Their resistance ranges between .5 ohm and 3 or more ohms (Stoelting No. 7076—.5 ohm; Harvard—3 ohms). An induction coil in series with a magnet requires a 2 to 3 volt and a .4 to 1 ampere current. An average resistance of all the instruments is about 1.5 ohms. Practically, the above amperages may be decreased within certain limits if the voltages are correspondingly increased, and vice versa. Individual needs will determine the number of instruments to be used. In this laboratory accommodations are provided for sections of thirty-five students each, and a maximum of sixty-five instruments is permitted.

Great increases in the line current must be avoided, and in order to determine the current necessary to keep this rise in the line amperage below any desired maximum, say 15 per cent., it is of advantage to keep in mind the following formulæ:

The current in amperes (i) equals the potential in volts (e) divided by the resistance in ohms (r).

$$i = \frac{e}{r} \quad \text{or} \quad e = ir \tag{1}$$

The conductance of two wires in parallel equals the sum of the two separate conductances, conductance being the inverse of resistance.

$$\frac{1}{r} = \frac{1}{r'} + \frac{1}{r''} \quad \text{or} \quad r \frac{r'r''}{r' + r''} \tag{2}$$

The amount of current passing through each of two wires in parallel is inversely proportional to its resistance.

$$i' : i'' = r'' : r' \qquad (3)$$

The amount of current passing through two wires in parallel equals the sum of the two separate currents.

$$i = i' + i''. \qquad (4)$$

As an illustration, a rheocord, taking 2 amperes from a 110-volt main, has a resistance of 55 ohms (formula 1) and 2 volts drop for each ohm. Shunt in a 1.5 ohm signal magnet on this line at two points, *A* and *B*, between which there are 2 ohms and consequently 4 volts. The intervening resistance becomes by formula (2) .85 ohm and is therefore reduced 1.15 ohms. The total line then has a resistance of 53.85 ohms and a current of 2.04 amperes (formula 1). Between *A* and *B* the voltage becomes $2.04 \times .85$ or 1.75 (formula 1) and the solving of equations from formulæ (3) and (4) shows the line amperage so divided that .85 ampere passes through the line and 1.15 amperes pass through the instrument. Accordingly, the magnet receives a current of 1.75 volts and 1.15 amperes, which is sufficient. But, should twelve such instruments be connected to similar sections of the line, the resistance would be reduced 1.15 ohms for each section and 13.8 ohms for the twelve sections giving the line a resistance of only 41.2 ohms and a current increased to almost 3 amperes (formula 1). The point is that the shunting in of too many instruments on a 2 ampere system would raise the amperage beyond the safe carrying capacity of the wire. The danger in this case is eliminated by using 3 or 4 instruments only, which can be operated across 8 or 10 ohms of resistance. Thus two parallel 32-candle-power lamps connected in series with 10 ohms of wire will furnish about 2 amperes and will operate instrument circuits of 1.5 or more ohms. Several such systems are required for large classes and the total amperage supply is necessarily high.

Figuring with greater amperages on a single line, it is found that an 11-ampere line will accommodate sixty-five instruments on separate shunts and keep the rise in amperage below 15 per cent. This is easily determined: on a 10-ohm line carrying 11 amperes, let there be between two points *A* and *B* a potential of 2 volts and a resistance of .18 ohm, each ohm having a drop of 11 volts. With a 1.5 ohm instrument shunted in, there is found a resistance of .16 ohm (differing by .02 ohm from the original .18 ohm), a potential of 1.76 volts, and a current through the instrument of 1.2 amperes. Sixty-five instruments averaging 1.5 ohms each, even when shunted in simultaneously on separate sections, give a total reduction of 1.3 ohms, and leaving 8.7 ohms in the line allow the passage of 12.6-ampere current, which is an increase of 15 per cent. above the normal. But, as less than twenty machines ordinarily are operating at any instant, there can be a resistance not reduced more than .4 ohm, a current not greater than 11.5 amperes and hence an amperage rise not over 5 per cent.

Third, Resistor Used.—Most of the electricity passing through a line is transformed into heat energy and the temperature of the conductor rises until the heat generated by the current equals the heat dispersed per unit of time. This heat rise, other things being equal, varies to a large degree inversely with the amount of radiating surface, which again is determined by the size, length and resistivity of the wire as well as its actual resistance. A large heat rise reduces the radiating surface necessary, and for a short wire a high resistivity must be used. For a moderate heat rise as 150° F. the radiating surface becomes proportionately larger and a correspondingly moderate resistivity is demanded on a short line carrying 5 or more amperes. Comparative resistances of resistors range between 1 and 65 times that of copper. For a 2 ampere system ordinary carbon lamps and any wire of high resistance as B. & S. No. 18 "Nichrome" is satisfactory. In the "Multiple Unit" system, which, carrying 11 amperes, has 10 ohms of resistance and is allowed an arbitrary heat rise of 160° F., the resistivity for a line made as short as possible for compactness is found to be about twenty times that of copper. As an example No. 15 B. & S. 18 per cent. German silver wire 19 times as

resistant as copper and carrying 11 amperes will give a heat rise of about 160° F. The length is less than 200 feet. In selecting wire for conditions other than those given above, the different wire capacity tables may be consulted for various heat rises, lengths, etc., that are easily obtained from wire manufacturers. The choice will lie mainly with iron, 18 per cent. and 28 per cent. German silver, "climax" and nickel-chromium wires or their equivalents given under various trade names. Their resistances are, respectively, seven, twenty, thirty, fifty and sixty times that of copper.

Fourth, Unit System Installed.—The "individual unit" system, as previously mentioned, carrying 2 amperes, is applicable for a limited number of certain instruments, particularly those of higher resistance. Several such systems are necessary for class work. Jackson's[2] "single unit" system consists essentially of one large frame over which is strung the resistance line, and has a capacity for a large number of instruments. This has in general all the favorable points of the shunt rheocord system, but the chief drawback is that such a frame is situated at one place from which all tapping wires must lead. In class work this may incur confusion in identifying individual tappings, and more especially necessitates the running of an excessive amount of wire from the frame to each table. Further, it is desirable that each machine, particularly inductoria, has its own separate connection to the resistance board in order that its operating current may be varied at will and may not be affected by the working of any other instrument, as is the case when one or more are placed in parallel with it. The "multiple unit" system eliminates this objection to the "single unit" by dividing the latter into several sectional units connected in series and placing one section near each table. Confusion is avoided, extensive wiring unnecessary, and quick variations of currents to individual instruments readily made.

Fifth, Miscellaneous Details.—In general, these are for convenience and safety and concerned with electrical rules and regulations. The main leads and the wires connecting the sectional units should be insulated copper large enough to carry the desired current (B. & S. No. 16—6 amperes, No. 14—12 amperes and No. 12—15 amperes). All connections are thoroughly fastened or spliced and soldered if necessary.

Sectional or individual units may be constructed to suit individual preferences, the only requirement being proper insulation of the bare wire. Stringing the resistance line over wooden frames, even asbestos lined, is not always advisable because of possible dangers from accidental overheating. Slabs of slate or stone are more preferable since they permit ample insulation and protection. The resistant units in the author's "multiple unit" system are slate slabs 14 in. x 12 in. x 1 in. in size with a ¼-in. beveled edge, a ¼-in. hole near each corner for fastening unit to the wall being separated from it by 2-in. porcelain spools. One inch in along each long side a row of holes is drilled to fit 3/16 in. stove bolts, the holes being ¾ in. apart and so located that the wire when strung shall run in a zigzag manner. Through the holes bolts are inserted from the rear surface; a washer is placed on each next to the slate on the front surface; and the wire is strung tightly from bolt to bolt, each of which is finally tightened by a single washer and nut. The bolt ends should project out free ½ in. so that spring clips of the tapping wires may be easily attached where direct wire tapping is less convenient or not desired. Wire strands between bolts are 10 in. long and each strand produces approximately a .5-volt drop in the current. Thus a 2-volt drop is obtained across four strands. If tappings are to be made from the bolt ends only, the resistance wire may be coiled spirally, thus shortening the span of the strands and materially diminishing the size of the units.

Tapping wires are twisted flexible lamp cord of ten or other convenient length with ends numbered and all lightly soldered to prevent the strands from breaking and with spring clips, fastened to one pair of ends, for attaching to the bolt ends or the resistance wire.

[2] Jackson, *Journal A. M. A.*, 1912, Vol. LVIII, p. 1011.

Into the tapping wires between the spring clips and instrument connections ½ or 1 ampere fuses, which "blow out" with 1½ to 2½ amperes of current, may be inserted. Provision is made for connecting in series one or, in some tapping sets, two instruments.

The system may be briefly described as follows: The "multiple unit" system, used in the pharmacology laboratory of the Northwestern University Medical School consists of 8 sectional units, connected in series, strung with 10 ohms of No. 15 B. & S. German silver 18 per cent. nickel alloy wire about 200 feet long. The 110-volt, 11-ampere current enters at the positive main, passes through a cartridge fuse and switch on an enclosed switchboard, to resistance unit No. 1, to unit No. 2, so on consecutively to unit No. 8, and back through the switch and a fuse to the negative main. A pilot light is connected in parallel across some unit to indicate when current passes through the line. From varying points on any unit, double-fused flexible lamp cord may be led off to an inductorium. Similarly, a signal magnet, or an inductorium with a signal magnet in series, may be connected. Each strand is 10 in. long and has a .5-volt potential. Single instruments operate across a 3 or 4 strand shunt (1.5 to 2 volts), two instruments in series operate across a 4 to 6 strand shunt (2 to 3 volts). All instrument circuits take .5 to 1.5 amperes, according to their resistance, while during the passage of the current the voltage drops from .05 to .3 volt, due to the decreased resistance across the shunt. It is wise to test each instrument, because of possible differences in its resistance, with the volt-meter and the ammeter before using it in regular work. The "multiple unit" system is likewise admirably adapted not only for tissue stimulation with the direct current as previously mentioned, but also for physiologic chemical work as the determination of copper in sugar analysis, etc. The cost of such an outfit will range between 5 and 15 dollars, including units, switch box, wire and tapping cords. Since the operating expense is but a few cents per hour and the "system" is a permanent fixture, the actual expense is much less than that of dry batteries, which must be frequently renewed.

A few possible dangers are to be remembered. If the negative main be connected to the ground, as occurs with some power plants, "grounding" of the positive main from any point along the resistance line may take place through a tapping wire, either directly by contact with water pipes, radiators, etc., or indirectly through instruments not insulated from stands which themselves are grounded. In either case the grounding wire and any instrument in series with it takes part of the line current which usually burns out the small fuses in the tapping wire but, if not, may be so large as to injure the instrument. Signal magnets, if not insulated, may "short circuit" by permitting the current to flow from one instrument to another, either through a common stand rod, or through metal writing levers touching a kymograph drum not covered with tracing paper. This will prevent the passage of sufficient current through the instruments which then do not work properly. With a 2-ampere system for 3 to 4 instrument capacity, only the last 8 or 10 ohms of the wire nearest the negative main should be used. This, as well as the fusing of the individual tapping wires, minimizes the danger. Likewise, it is preferable if possible to have instruments operated on the negative side of a larger ampere line in order to reduce the seriousness of grounding. Students should be given the following instructions to prevent these occurrences.

First, *always* make sure that the line has no possible "ground" before the main current is switched on.

Second, tap *last* from a resistance unit when setting up an apparatus and disconnect *first* from the unit when changing instruments or through using apparatus.

Third, *insulate* signal magnets and other electrical apparatus from metal stands by heavy rubber tubing and keep tracing paper on drums which are in contact with metal writing levers.

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